

Comprehensive NASA Cis-Lunar Earth Moon Libration Orbit Reference and Web Application

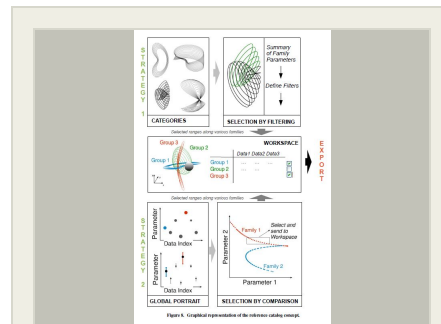
Completed Technology Project (2013 - 2014)



Project Introduction

This work will provide research and trajectory design analysis to develop a NASA Cis-Lunar / Earth-Moon Libration Orbit Reference and Web Application. A compendium of feasible Earth-Moon libration transfers and orbits, it will bring multi-body orbits to a larger venue and offer design options from a different perspective, no longer thinking only in terms of point designs, but interactive exploration with insight into the larger space. It will provide the analyst with efficient access to user-defined and standard design parameters to allow efficient and fully informed decisions regarding robotic and habitat missions in cis-lunar space.

To finalize a comprehensive NASA Cis-Lunar / Earth-Moon Libration Orbit Reference and Web Application begun using FY13 IRAD funding approved in May 2013. This GSFC reference will be available as a searchable web-based application to explore design options and generate essential trajectory data permitting both astrodynamics experts and non-experts (proposal teams and systems designers) to determine useable trajectories in the Earth-Moon (EM) system. It can be used by HQ management, JSC's DSH habitat concept teams, HEOMD, and other analysis teams to develop designs without performing numerous time-consuming point designs or trades. Completing such a reference would maintain GSFC's leadership role in EM libration orbit design and operations while providing other study teams with instant designs and quotes on mission design parameters such as delta-V (DV), propellant budgets, mission durations, launch requirements, and libration-orbit parameters. The related objectives of this study fall into four specific categories: detailed analysis of transfers; orbital maintenance and evolution; and application to a variety of other mission types, e.g. distant retrograde orbits useful for human exploration.



Reference Catalog Concept design

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- **Provide Detailed Analysis of EM libration transfers:** This effort includes direct transfers, transfers using lunar gravity assist, and transfers via multi-body dynamics (manifolds) to reach EM $L_{1,2}$ orbits. This analysis would cover the entire design space and complete trades for any and all transfers to/from EM L_1 and EM L_2 and transfers between them. The current design process can be painstakingly slow, especially for point design using numerical simulations. We will apply the successful IRAD Adaptive Trajectory Design (ATD) tool to assist in generating most of these designs. Working with Purdue University would allow us to generate complete families of transfers.
- **Provide Stationkeeping and Evolution Analysis of all EM libration orbit types:** This includes any orbit type (quasi-halo, halo, Lissajous, Lyapunov orbits, rectilinear, etc.). With the recent operational support of ARTEMIS, which maintained two spacecraft in both EM L_1 and EM L_2 orbits, we implemented an optimal stationkeeping strategy that minimized DV requirements. But ARTEMIS represents only a subset of all possible orbits and constraints. We need to examine not only the stationkeeping of various EM orbit types, but also the perturbation effects of un-modeled or mis-modeled s/c properties such as momentum management and response to environmental conditions on our stationkeeping methods and navigation performance. The result of such a study would be to document ΔV budgets required for all EM libration orbit types, providing any team with ready access to critical mission planning data.
- **Explore Lunar resonant orbits and Distant Retrograde Orbits (DROs).** These orbit designs are becoming more popular with missions such as TESS using a resonant orbit and the Asteroid Return Mission using a DRO. These orbits can also have stable/unstable manifolds which we can apply to our design.
- **Develop an Interactive Web Catalog.** A development of a broadly useful NASA Cis-Lunar / Earth-Moon Libration online catalog necessary for use across NASA. Such an orbit reference does not currently exist. It will be populated by the analysis and algorithms from the objectives above.

Anticipated Benefits

NASA has recently invested major time commitments in determining how to operate missions in Earth-Moon (cis-lunar) regions, specifically the Earth-Moon Libration orbits, in lunar orbit, Distant Retrograde Orbits (DROs), and on the lunar surface. Recent NASA concept calls from AA/SMD Mars Exploration Program, working with the AA/HEOMD, OCT, and the OCS along with HQ guidelines requested design analysis for the use of the Earth-Moon (EM)

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Goddard Space Flight Center (GSFC)

Responsible Program:

Center Innovation Fund: GSFC CIF

Project Management

Program Director:

Michael R Lapointe

Program Manager:

Peter M Hughes

Project Manager:

John C Adams

Principal Investigator:

David C Folta

Co-Investigator:

Kathleen C Howell

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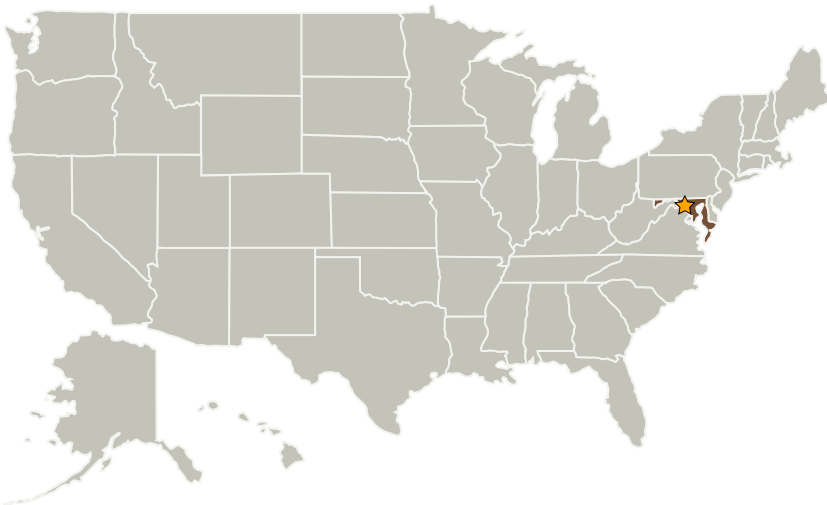


libration orbits for various robotic and human missions. For example, the 2012 NASA Mars concept call stated "*a particular interest in analyses of trajectories of Earth-Moon L_2 .*" Additionally there are many requests (via JSC, HQ, GSFC, and contractors such as LM and Boeing) for EM libration orbit analysis to design long-duration human exploration missions, habitats, and to understand lunar way-points. The recent analysis of the ARRM mission required both libration orbit transfer design and DROs. The infusion of EM libration orbits into mission designs is part of almost every NASA guideline.

There are an infinite design possibility of Earth-moon libration orbits, This tool and web site provides the user(NASA or contractor) a way to generate multiple trades of DVs, fuel, Mission concepts, Mission orbit types, and durations in an easy GUI application. This tool reduces the cost of analysis to preform these trades.

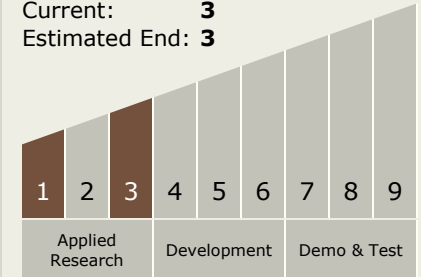
Same as to NASA unfunded and planned missions. This tool reduces the cost of analysis to preform Earth-moon mission orbit trades.

Primary U.S. Work Locations and Key Partners



Technology Maturity (TRL)

Start: **1**
Current: **3**
Estimated End: **3**



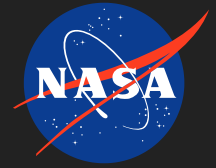
Technology Areas

Primary:

- TX17 Guidance, Navigation, and Control (GN&C)
 - └ TX17.2 Navigation Technologies
 - └ TX17.2.6 Rendezvous, Proximity Operations, and Capture Trajectory Design and Orbit Determination

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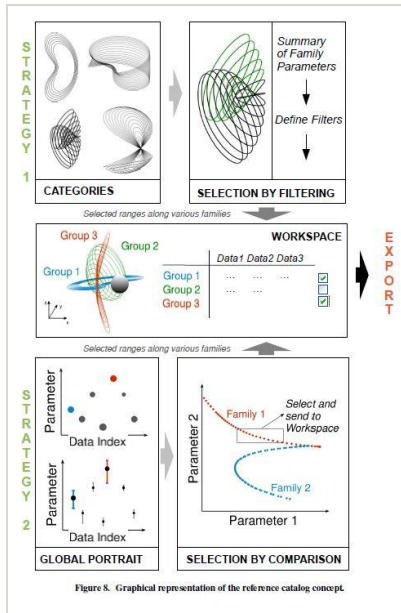
Organizations Performing Work	Role	Type	Location
★Goddard Space Flight Center(GSFC)	Lead Organization	NASA Center	Greenbelt, Maryland
Purdue University-Main Campus	Supporting Organization	Academia	West Lafayette, Indiana

Co-Funding Partners	Type	Location
Purdue University-Main Campus	Academia	West Lafayette, Indiana

Primary U.S. Work Locations

Maryland

Images



Reference Catalog Concept design

Reference Catalog Concept design
<https://techport.nasa.gov/image/3067>

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Stories

AN EARTH-MOON SYSTEM TRAJECTORY DESIGN REFERENCE CATALOG
(<https://techport.nasa.gov/file/1693>)

Project Website:

<http://aetd.gsfc.nasa.gov/>